

II. "Note on the Necessity of using Well-Annealed and Homogeneous Glass for the Mirrors of Telescopes." By A. A. COMMON, LL.D., F.R.S. Received November 18, 1891.

In 1880 I ordered of the St. Gobain Glassworks, through their London agent, M. de Grand Ry, a disk of glass for the mirror of a 5-foot telescope. The limit of weight imposed by the manufacturers permitted a disk of about 61 inches diameter and 5 inches thickness; this was made with a hole through the middle of 10 inches, in order to enable the telescope to be used as a Cassegrain telescope if required.

Not being in a position to begin work at that time, the disk of glass was left in its case, standing against a wall, at a slight angle, till 1886, when it was put upon a grinding machine to be worked into a mirror. With the intention of acquiring the necessary skill to make a good mirror, I intended to make many mirrors of this one disk by successive re-grinding and re-figuring.

The first polishing was done before the whole surface of the glass was brought down to a uniform face.

On inspection by Foucault's method of testing at the centre of curvature, the image of a round hole was found to be very elliptical; very little attention was paid to this at the time, as it was thought that subsequent work would bring all right. After many re-grindings, in each of which a practically new mirror was made, this elliptic appearance of the image persisted. Local polishing was tried, to improve the figure of revolution, without success, in fact it made matters worse. The telescope mounting being ready in 1888, the mirror was finished as well as possible, and put into the telescope, where a star could be examined, this not being possible when the mirror was on the machine; for photographic purposes the mirror was fair, giving good stellar images, but for visual work, with moderate powers, the definition did not come up to the required standard.

It was of interest to find the cause of this bad image; at first it was thought that the long time the disk had stood on edge, at an angle, had caused it; in this case it might in time become less; but, after being re-made in 1889, and again in 1890, the mirror was, if anything, worse than before. When polished, in certain lights broad bands of colour, red and blue, could be seen in the body of the glass about a foot from the edge all round, indicating in my opinion much internal tension, probably due to imperfect annealing.

Another disk was ordered in December, 1888, as soon as the first had been tried in the telescope. This second disk was delivered in 1890 and made into a mirror, without showing in the slightest manner any of the defects of the first.

In the course of the work on this last disk, a discovery was ma

that most probably explains the cause of failure of the first; in the process of polishing a certain amount of heat is produced, and it was always the custom to allow the mirror to cool down for some hours before testing; it was also always considered that some slight change of focal length was caused by the heat, but I was quite unprepared, on testing the mirror directly after polishing, in order to determine what this change amounted to, to find the enormous amount thus produced. After two hours figuring with a 15-inch polisher, with the face of harder resin than usual, so that the friction and heat were below the average amount in one polishing, the change of focal length was found to be 4 inches, that is to say, the image was made 4 inches further from the mirror than the usual place, or the mirror had at that time a radius of curvature 2 inches greater than the normal; in the course of three hours this had disappeared, and the image was produced at the normal place. As the whole trouble of the first mirror was caused by opposite diameters of the same zone coming to a focus in planes differing by about  $\frac{1}{10}$  of an inch, it can easily be seen that this may have been caused by the failure of the glass to contract in a perfect and regular manner; in figuring, a large amount of the work would necessarily be done on the expanded glass, and it is reasonable to suppose that the figure thus given would be correct while the glass was in this state, but that on cooling, unless the glass contracted regularly, this correct figure would be lost.

After the second mirror was finished the first mirror was re-ground, and the polishing was done very slowly, half-an-hour in the morning, and the same time in the evening, with manifest improvement in the figure, but still without getting rid of all the defects.

That the fault was in the glass there is no doubt; the method of working adopted shows, in the case of the second 5-foot, and in other mirrors of 20-, 30-, and 36-inch mirrors, that a perfect surface of revolution can always be obtained if the glass is good; unless this perfect surface of revolution is obtained, it is quite hopeless to expect a good mirror.

The makers could not re-anneal the first disk, but they have undertaken, in a very handsome manner, to replace it by a new one; this I hope will be as good as the second one made by them, which is as nearly as possible perfect.